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I, Yoshihiko Niwa c/o Murata Manufacturing Co., Ltd., at 10-1, Higashikotari 1-chome Nagaokakyo-shi, Kyoto-fu, Japan,
do hereby certify that I am conversant with the English and Japanese languages,
and I further certify that to the best of my knowledge and belief
the attached English translation is a true and correct translation of the Japanese patent application No. 2002-253595 filed on August 30, 2002.

Signed this on April 12 , 2005

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[Name of Document] Application for Patent

[Reference No.] 32-0092

[Date of Filing] August 30, 2002

[Addressee] Commissioner of the Patent Office

[Int. Cl.] C04B 35/46

H01B 3/12

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[Prepayment Registration No.] 005304

[Amount of Payment] 21000

[List of Documents Attached]

[Name of Document]	Specification	1
[Name of Document]	Drawings	1
[Name of Document]	Abstract	1
[Proof]	Required	

JP Application No. 2002-253595

[Name of Document] SPECIFICATION

[Title of the Invention] HIGH FREQUENCY DIELECTRIC CERAMIC COMPOSITION, DIELECTRIC RESONATOR, DIELECTRIC FILTER, DIELECTRIC DUPLEXER, AND COMMUNICATION DEVICE

[Claims]

[Claim 1] A high frequency dielectric ceramic composition comprising:

as a major component a composition which contains a rare earth element (Re), Al, Sr, and Ti as metal elements and has a composition formula expressed by a molar ratio of $aRe_2O_3 - bAl_2O_3 - cSrO - dTiO_2$ in which a, b, c, and d satisfy the following formula;

$0.113 \leq a \leq 0.172$,

$0.111 \leq b \leq 0.171$,

$0.322 \leq c \leq 0.388$,

$0.323 \leq d \leq 0.396$, and

$a + b + c + d = 1.000$; and

0.01 to 2 parts by weight on a Fe_2O_3 conversion basis of Fe as an element, based on 100 parts by weight of the major component.

[Claim 2] A high frequency dielectric ceramic composition according to Claim 1, wherein the rare earth element (Re) comprises La, or La and at least one of the other rare earth elements.

[Claim 3] A dielectric resonator in which a dielectric

ceramic is electromagnetic field coupled with input-output terminals to be operated, wherein the dielectric ceramic is made of the high frequency dielectric ceramic composition defined in Claim 1 or 2.

[Claim 4] A dielectric filter comprising the dielectric resonator defined in Claim 3 and an external coupling means.

[Claim 5] A dielectric duplexer comprising at least two dielectric filters, input-output connecting means connected to the dielectric filters, respectively, and an antenna-connecting means connected to both of the dielectric filters, at least one of the dielectric filters being the dielectric filter defined in Claim 4.

[Claim 6] A communication device comprising the dielectric duplexer defined in Claim 5, a transmission circuit connected to at least one of the input-output connecting means for the dielectric duplexers, a reception circuit connected to at least one of the input-output connecting means which is different from the above-described input-output connecting means to which the transmission circuit is connected, and an antenna connected to the antenna-connecting means for the dielectric duplexer.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a high frequency

dielectric ceramic composition for use in a high frequency region such as microwave and millimeter-wave regions, a dielectric resonator, a dielectric filter, a dielectric duplexer, and a communication device each using the same.

[0002]

[Description of the Related Art]

Heretofore, dielectric ceramics have been widely used for dielectric resonators, circuit substrate materials, and so forth which operate in a high frequency region such as microwave and millimeter-wave regions.

[0003]

For example, dielectric characteristics required for the high frequency dielectric ceramics are as follows. (1) The wavelength of an electromagnetic wave is reduced to $1/(\varepsilon r)^{1/2}$ in a dielectric. Accordingly, to meet requests for the size-reduction, it is required for the dielectric constants (ε_r) to be large. (2) The dielectric losses should be low, i.e., the Q values should be high. (3) The stability of the resonance frequencies for temperature should be high, i.e., the temperature coefficients (τ_f) of the resonance frequencies should be near 0 (ppm/°C).

[0004]

Heretofore, as the above-described dielectric ceramics, Re_2O_3 - Al_2O_3 - SrO - TiO_2 (Re: rare earth element) type materials, and the materials containing Mn added thereto are

disclosed, e.g., in Japanese Unexamined Patent Application Publication No. 11-71171 and Japanese Unexamined Patent Application Publication No. 2000-203934.

[0005]

[Problems to be Solved by the Invention]

The Re_2O_3 - Al_2O_3 - SrO - TiO_2 type materials of the related art are superior in that the dielectric constants (ε_r) are high, the Q values are high, and the temperature coefficient (τ_f) of the resonance frequency can be controlled to be near zero. However, with recent advancement of the communication enterprises, high frequency electronic parts have been required to have higher qualities. Moreover, materials for dielectric ceramics have been required to have a higher Q value than the related art materials.

[0006]

Accordingly, it is an object of the present invention to provide a high frequency dielectric ceramic composition which has a high Q value compared with the related art Re_2O_3 - Al_2O_3 - SrO - TiO_2 type material, and have a high dielectric constant (ε_f) and a small temperature coefficient (τ_f) of the resonance frequency which are on the same level of those of the related art Re_2O_3 - Al_2O_3 - SrO - TiO_2 type material, and to provide a dielectric resonator, a dielectric filter, a dielectric duplexer, and a communication device each using the high frequency

dielectric ceramic composition.

[0007]

[Means for Solving the Problems]

To achieve the above-described object, the high frequency dielectric ceramic composition of the present invention comprises: as a major component a composition which contains a rare earth element (Re), Al, Sr, and Ti as metal elements and has a composition formula expressed by a molar ratio of aRe_2O_3 - bAl_2O_3 - $cSrO$ - $dTiO_2$ in which a, b, c, and d satisfy the following formula; $0.113 \leq a \leq 0.172$, $0.111 \leq b \leq 0.171$, $0.322 \leq c \leq 0.388$, $0.323 \leq d \leq 0.396$, and $a + b + c + d = 1.000$; and 0.01 to 2 parts by weight on a Fe_2O_3 conversion basis of Fe as an element, based on 100 parts by weight of the major component.

[0008]

Characteristically, the rare earth element (Re) comprises La, or La and at least one of the other rare earth elements.

[0009]

In the dielectric resonator of the present invention having a dielectric ceramic electromagnetic field coupled with input-output terminals to be operated, the dielectric ceramic is made of the above-described high frequency dielectric ceramic composition.

[0010]

The dielectric filter of the present invention comprises the above-described dielectric resonator and an external coupling means.

[0011]

The dielectric duplexer of the present invention comprises at least two dielectric filters, input-output connecting means connected to the dielectric filters, respectively, and an antenna-connecting means connected to both of the dielectric filters, at least one of the dielectric filters being the above-described dielectric filter.

[0012]

The communication device of the present invention comprises the above-described dielectric duplexer, a transmission circuit connected to at least one of the input-output connecting means for the dielectric duplexers, a reception circuit connected to at least one of the input-output connecting means which is different from the above-described input-output connecting means to which the transmission circuit is connected, and an antenna connected to the antenna-connecting means for the dielectric duplexer.

[0013]

[Description of the Embodiments]

Fig. 1 is a cross-sectional view of a TE01δ mode dielectric resonator 11 which is an example of the

dielectric resonator of the present invention. Referring to Fig. 1, a dielectric resonator 11 is provided with a metallic case 12. A columnar dielectric ceramic 14, supported by a support 13, is arranged in the space within the metallic case 12. An input terminal 15 and an output terminal 16 are supported by the metallic case 12 while the terminals are insulated from the metallic case 12. The dielectric ceramic 14 is electromagnetic field coupled with the input terminal 15 and the output terminal 16 to be operated. Only a signal having a predetermined frequency, input via the input terminal, is output via the output terminal. The dielectric ceramic 14 provided in the dielectric resonator 11 is formed of the high frequency dielectric ceramic composition of the present invention.

[0014]

Fig. 2 is a perspective view of a TEM mode dielectric resonator which is another example of the dielectric resonator of the present invention. Fig. 3 is a cross-sectional view taken along plane a-b of a dielectric resonator 21 shown in Fig. 2. Referring to Figs. 2 and 3, the dielectric resonator 21 comprises a prism-shaped dielectric ceramic 22 having a through-hole, in which an inner conductor 23a is formed in the through-hole, and an outer conductor 23b is formed in the periphery thereof. The input-output terminals, i.e., external coupling means are

electromagnetic field coupled with the dielectric ceramic 22 to be operated as a dielectric resonator. The dielectric ceramic 22 constituting the dielectric resonator 21 is formed of the high frequency dielectric ceramic composition of the present invention.

[0015]

Fig. 1 shows an example of the TE01δ mode dielectric resonator, and Fig. 2 shows an example of the prism-shaped TEM mode dielectric resonator, as described above. The present invention is restricted to these examples. The high frequency dielectric ceramic composition of the present invention may be also used for dielectric resonators having other shapes and other TEM modes, TE modes and TM modes.

[0016]

Fig. 4 is a block diagram of an example of the communication device of the present invention. The communication device 30 comprises a dielectric duplexer 32, a transmission circuit 34, a reception circuit 36, and an antenna 38. The transmission circuit 34 is electrically connected to an output-connecting means 40 of the dielectric duplexer 32. The reception circuit 36 is connected to an output-connecting means 42 of the dielectric duplexer 32. The antenna 38 is connected to an antenna-connecting means 44 of the dielectric duplexer 32. The dielectric duplexer 32 contains two dielectric filters 46 and 48. Each of the

dielectric filters 46 and 48 comprises the dielectric resonator of the present invention having an external-coupling means connected thereto. For example, they are formed by connecting external-coupling means 50 to the input-output terminals of the dielectric resonators 11 shown in Fig. 1. One dielectric filter 46 is connected between the input-connecting means 40 and the other dielectric filter 48. The other dielectric filter 48 is connected between the one dielectric filter 46 and the output-connecting means 42.

[0017]

As described above, the high frequency dielectric ceramic composition of the present invention contains as a major component a composition containing as metal elements a rare earth element (Re), Al, Sr, and Ti, having a composition formula by a molar ratio of aRe_2O_3 - bAl_2O_3 - $cSrO$ - $dTiO_2$ in which a, b, c, and d satisfy formulae of $0.113 \leq a \leq 0.172$, $0.111 \leq b \leq 0.171$, $0.322 \leq c \leq 0.388$, $0.323 \leq d \leq 0.396$, and $a + + b + c + d = 1.000$. The ceramic composition contains 0.01 to 2 parts by weight, on a Fe_2O_3 conversion basis, of Fe as an element, based on 100 parts by weight of the major component.

[0018]

By employing the above-defined composition range, the high frequency dielectric ceramic composition can be

provided which has a higher Q value than the related art Re_2O_3 - Al_2P_3 - SrO - TiO_2 type material, such a high dielectric constant (ε_r) as the related art Re_2O_3 - Al_2P_3 - SrO - TiO_2 type material, and a small temperature coefficient (τ_f) of the resonance frequency.

[0019]

[Embodiments]

Hereinafter, the present invention will be described with reference of more specific examples.

[0020]

(Example 1)

As starting materials, powders of La_2O_3 which is a rare earth oxide (Re_2O_3), aluminum oxide (Al_2O_3), strontium carbonate ($SrCO_3$), and titanium oxide (TiO_2) each having a high purity were prepared.

[0021]

Then, these raw materials were mixed so as to obtain compositions having a composition formula of aRe_2O_3 - bAl_2O_3 - cSrO - $dTiO_2$ in which the coefficients (molar ratio) a, b, c, and d are indicated in Tables 2 and 3.

[0022]

[Table 1]

Sample	La2O3 a	Al2O3 b	SrO c	TiO2 d	Fe2O3 (parts by weight)	εr	Q×f (GHz)	Q×f value-increasing ratio (%)	τf (ppm/°C)
1 *	0.137	0.137	0.363	0.363	0	39	67800	—	1.1
2	0.137	0.137	0.363	0.363	0.5	39	80600	18.9	2.1
3 *	0.136	0.138	0.361	0.365	0	38	64000	—	0.2
4	0.136	0.138	0.361	0.365	0.5	38	75400	17.8	0.4
5 *	0.148	0.139	0.346	0.367	0	38	57600	—	4.8
6	0.148	0.139	0.346	0.367	0.5	38	67000	16.3	4.9
7 *	0.142	0.139	0.364	0.355	0	38	63400	—	−1.5
8	0.142	0.139	0.364	0.355	0.5	38	75400	18.9	−2.1
9 *	0.153	0.121	0.367	0.359	0	37	52400	—	−5.7
10	0.153	0.121	0.367	0.359	0.5	37	60900	16.3	−5.3
11 *	0.143	0.147	0.358	0.352	0	38	62500	—	−3.8
12	0.143	0.147	0.358	0.352	0.5	38	77600	24.2	−4.4
13 *	0.151	0.148	0.354	0.347	0	37	67800	—	−7.2
14	0.151	0.148	0.354	0.347	0.5	37	77700	14.6	−8.5
15 *	0.154	0.154	0.346	0.346	0	37	64600	—	−10
16	0.154	0.154	0.346	0.346	0.5	37	76400	18.2	−9.4
17 *	0.139	0.159	0.331	0.371	0	33	50500	—	−1.4
18	0.139	0.159	0.331	0.371	0.5	33	59800	18.4	−1.1
19 *	0.156	0.160	0.345	0.339	0	37	68200	—	−11.8
20	0.156	0.160	0.345	0.339	0.5	37	80100	17.4	−10.9
21 *	0.150	0.157	0.340	0.353	0	34	64200	—	−23.8
22	0.150	0.157	0.340	0.353	0.5	34	76300	18.9	−24.9
23 *	0.162	0.165	0.337	0.336	0	36	70700	—	−13.9
24	0.162	0.165	0.337	0.336	0.5	36	84400	19.4	−14.7
25 *	0.165	0.168	0.330	0.337	0	35	69800	—	−19.5
26	0.165	0.168	0.330	0.337	0.5	35	81900	17.4	−18.4
27 *	0.171	0.171	0.329	0.329	0	33	62300	—	−22.4
28	0.171	0.171	0.329	0.329	0.5	33	73700	18.3	−23.4
29 *	0.161	0.161	0.355	0.323	0	36	53400	—	−14.8
30	0.161	0.161	0.355	0.323	0.5	36	65300	22.3	−15
31 *	0.172	0.168	0.330	0.330	0	31	62000	—	−27.7
32	0.172	0.168	0.330	0.330	0.5	31	72400	16.7	−28.6
33 *	0.141	0.161	0.322	0.376	0	33	48100	—	−18.4
34	0.141	0.161	0.322	0.376	0.5	33	57400	19.4	−17.3
35 *	0.132	0.142	0.366	0.360	0	40	65900	—	2.4
36	0.132	0.142	0.366	0.360	0.5	40	76600	16.2	3.3
37 *	0.129	0.129	0.371	0.371	0	40	67800	—	5.1
38	0.129	0.129	0.371	0.371	0.5	40	80100	18.2	6.1
39 *	0.150	0.121	0.368	0.361	0	38	45300	—	−6.2
40	0.150	0.121	0.368	0.361	0.5	38	54000	19.2	−5.4

[0023]

[Table 2]

Sample	La2O3 a	Al2O3 b	SrO c	TiO2 d	Fe2O3 (parts by weight)	ε r	Q×f (GHz)	Q × f value-increasing ratio (%)	τ f (ppm/°C)
41 *	0.125	0.128	0.380	0.367	0	41	62400	—	8.4
42	0.125	0.128	0.380	0.367	0.5	41	73400	17.6	8.5
43 *	0.122	0.119	0.382	0.377	0	42	57700	—	15.4
44	0.122	0.119	0.382	0.377	0.5	42	68500	18.8	15.9
45 *	0.117	0.152	0.343	0.388	0	40	47400	—	5.1
46	0.117	0.152	0.343	0.388	0.5	40	56000	18.2	5.9
47 *	0.144	0.119	0.388	0.349	0	44	42300	—	10.2
48	0.144	0.119	0.388	0.349	0.5	44	50300	18.9	10.9
49 *	0.113	0.113	0.387	0.387	0	44	49800	—	24.3
50	0.113	0.113	0.387	0.387	0.5	44	59000	18.4	24.7
51 *	0.141	0.118	0.345	0.396	0	38	41400	—	14.3
52	0.141	0.118	0.345	0.396	0.5	38	50700	22.4	14.9
53 *	0.115	0.111	0.384	0.390	0	45	53500	—	27.1
54	0.115	0.111	0.384	0.390	0.5	45	62400	16.7	26.4
55 *	0.107	0.119	0.384	0.390	0	46	43200	—	35
56 *	0.159	0.179	0.331	0.331	0	29	58200	—	-41
57 *	0.085	0.085	0.415	0.415	0	57	40200	—	64
58 *	0.119	0.107	0.384	0.390	0	48	36000	—	38
59 *	0.174	0.138	0.347	0.341	0	34	23600	—	15
60 *	0.117	0.114	0.396	0.373	0	49	43200	—	38
61 *	0.194	0.194	0.306	0.306	0	27	53200	—	-42
62 *	0.170	0.166	0.361	0.303	0	29	52700	—	-34
63 *	0.170	0.166	0.302	0.362	0	25	32200	—	-18
64 *	0.117	0.114	0.371	0.398	0	52	37800	—	49

[0024]

Thereafter, the mixed powder was wet-mixed for 16 hours by means of a ball mill. Then, water was removed, and the powder was dried, and thereafter, was calcined at a temperature of 1100 to 1200°C for 3 hours. Thus, the calcined powder as the major component was produced.

[0025]

Subsequently, 0.5 parts by weight based on 100 parts by weight of the major component of iron oxide (Fe_2O_3) as a Fe compound was added to the calcined powder as shown in Tables 1 and 2. Then, an appropriate amount of a binder was added, and the powder was wet-crushed for 16 hours by means of a ball mill. Thus, an adjusted powder was produced.

[0026]

Thereafter, the adjusted powder was press-formed into a disk shape at a pressure of 1000 to 2000 kg/cm^2 and fired in the atmosphere at a temperature of 1500 to 1650°C for 4 hours. Thus, a sintered piece having a diameter of 10 mm and a thickness of 5 mm was obtained.

[0027]

The dielectric constant (ε_f) and the Q value of the sintered piece were measured at a frequency (f) of 6 to 8 GHz by the both-end shortening type dielectric resonator method. The Q x f value was calculated. The temperature coefficient (τ_f, 25°C to 55°C) of the resonance frequency was measured based on the TE010δ mode resonance frequency. Tables 1 and 2 show the results. It should be noted that in Tables 1 and 2, the samples with sample-numbers having "star marks" depart from the scope of the present invention. The other samples are within the scope of the present invention.

[0028]

As seen in Tables 1 and 2, in the case in which the major components having a composition formula of aRe_2O_3 - bAl_2O_3 - cSrO - $dTiO_2$ in which a, b, c, and d satisfy formulae of $0.113 \leq a \leq 0.172$, $0.111 \leq b \leq 0.171$, $0.322 \leq c \leq 0.388$, $0.323 \leq d \leq 0.396$, and $a + b + c + d = 1.000$ as in Samples 1 to 54, the sintered pieces have superior microwave dielectric characteristics. That is, the dielectric constants are high, i.e., at least 30, the Q x f values are high, i.e., at least 40,000 GHz, and the absolute values of the temperature coefficients (τf) of the resonance frequency are within 30 ppm/°C, i.e., nearly zero.

[0029]

On the other hand, in the case in which the compositions of the major components departs from the above-described range as seen in Samples 55 to 64, undesirably, the dielectric constants (εf) are less than 30, the Q x f values are less than 40,000 GHz, or the temperature coefficients (τ_f) of the resonance frequencies exceeds 30 (ppm/°C).

[0030]

Then, as seen in Samples having even sample-numbers in the range of 1 to 54, by addition of 0.5 parts by weight on a Fe_2O_3 conversion basis of Fe as an element, based on 100 parts by weight of a major component of which the composition formula is in the above-described range to

exhibits a superior microwave dielectric characteristic, the Q x f values are significantly high compared to those of the major components of which the compositions are the same as those of the above-described Samples except that no Fe_2O_3 is added (the sample having an odd number which is smaller by 1 than each of the sample having the above-mentioned even numbers). Thus, the Q value can be significantly increased by incorporating the Fe element into a Re_2O_3 - Al_2O_3 - SrO - TiO_2 type composition.

[0031]

(Example 2)

As starting materials, powders of La_2O_3 as a rare earth oxide (Re_2O_3), aluminum oxide (Al_2O_3), strontium carbonate ($SrCO_3$), and titanium oxide (TiO_2) each having a high purity were prepared.

[0032]

Subsequently, the raw materials were mixed so as to obtain compositions having a composition formula of $0.137La_2O_3$ - $0.137Al_2O_3$ - 0.363SrO - $0.363TiO_2$ (the coefficients are expressed by molar ratios). The composition was processed in a similar manner to that for Example 1. Thus, the calcined powders as the major components were obtained.

[0033]

[Table 3]

Sample	La2O3 a	Al2O3 b	SrO c	TiO2 d	Fe2O3 (parts by weight)	ε r	Q×f (GHz)	Q × f value-increasing ratio (%)	τ f (ppm/°C)
71 *	0.137	0.137	0.363	0.363	0	39	67800	—	1.1
72	0.137	0.137	0.363	0.363	0.5	39	80600	18.9	2.1
73	0.137	0.137	0.363	0.363	0.01	39	73700	8.7	1.4
74	0.137	0.137	0.363	0.363	0.02	39	75600	11.5	1.7
75	0.137	0.137	0.363	0.363	0.05	39	76700	13.2	1.6
76	0.137	0.137	0.363	0.363	1	39	79500	17.3	2.3
77	0.137	0.137	0.363	0.363	2	40	70900	4.5	2.5
78 *	0.137	0.137	0.363	0.363	3	40	64100	−5.4	3.4
79 *	0.137	0.137	0.363	0.363	4	40	56100	−17.2	3.4

[0034]

Subsequently, 0.01 to 4 parts by weight based on 100 parts by weight of the major component of iron oxide (Fe_2O_3) was added to the calcined powder as shown in Table 3. Then, an appropriate amount of a binder was added. The powders were wet-crushed for 16 hours by means of a ball mill. Thus, the adjusted powders were produced. Thereafter, sintered pieces were produced in a similar manner to that for Example 1.

[0035]

For the produced sintered pieces, the dielectric constant (εf), the Q × f value, and the temperature coefficient (τ_f) of the resonance frequency were determined. Table 3 shows the results. In Table 3, the samples having the sample numbers with star marks depart from the scope of the present invention. All of the other samples are within

the scope of the present invention.

[0036]

As seen in Table 3, as in Samples 72 to 77, the Q × f value can be enhanced by addition of 0.01 to 2 parts by weight of Fe_2O_3 based on 100 parts by weight of the major component, as compared with the case in which Fe_2O_3 is not added. To the contrary, when the addition amount of Fe_2O_3 exceeds 2 parts by weight as in Samples 78 and 79, the Q × f value is decreased. Accordingly, the content on an Fe_2O_3 conversion basis of Fe as an element is preferably in the range of 0.01 to 2 parts by weight based on 100 parts by weight of the major component.

[0037]

(Example 3)

As starting materials, powders of La_2O_3, Nd_3O_3, Ce_2O_3, Pr_2O_3, Pm_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3, Yb_2O_3, and Lu_2O_3, each having a high purity, were prepared. Moreover, powders of aluminum oxide (Al_2O_3), strontium carbonate ($SrCO_3$), and titanium oxide (TiO_2) were prepared.

[0038]

Subsequently, these raw materials were mixed so as to obtain a composition having a composition formula of $0.137Re_2O_3 - 0.137Al_2O_3 - 0.363SrO - 0.363TiO_2$ (the coefficients are expressed by a molar ratio) in which the Re

of Re_2O_3 is an element shown in Table 4. The mixed materials were processed in a similar manner to that for Example 1 to obtain calcined powders as the major components.

[0039]

[Table 4]

Sample	Re (Rare earth element)	Fe2O3 (parts by weight)	ε r	Q×f (GHz)	Q × f value-increasing ratio (%)	τ f (ppm/°C)
81 *	0.8La-0.2Nd	0	39	64300	—	1.3
82	0.8La-0.2Nd	0.5	39	73500	14.3	1.5
83 *	0.5La-0.5Nd	0	38	62500	—	0.8
84	0.5La-0.5Nd	0.5	38	70400	12.7	1.5
85 *	0.2La-0.8Nd	0	38	61000	—	0.5
86	0.2La-0.8Nd	0.5	38	69700	14.3	0.0
87 *	0.8La-0.2Ce	0	39	59800	—	0.7
88	0.8La-0.2Ce	0.5	39	69800	16.7	0.9
89 *	0.8La-0.2Pr	0	39	62300	—	0.8
90	0.8La-0.2Pr	0.5	39	72100	15.8	1.2
91 *	0.8La-0.2Pm	0	39	61900	—	0.4
92	0.8La-0.2Pm	0.5	39	70800	14.3	0.1
93 *	0.8La-0.2Sm	0	39	62700	—	-0.2
94	0.8La-0.2Sm	0.5	39	73700	17.6	0.3
95 *	0.8La-0.2Eu	0	39	52300	—	0.1
96	0.8La-0.2Eu	0.5	39	60400	15.4	-0.2
97 *	0.8La-0.2Gd	0	38	57800	—	-0.4
98	0.8La-0.2Gd	0.5	38	64800	12.1	0.5
99 *	0.8La-0.2Tb	0	38	59800	—	-0.7
100	0.8La-0.2Tb	0.5	38	70700	18.2	-0.2
101 *	0.8La-0.2Dy	0	38	61500	—	-0.1
102	0.8La-0.2Dy	0.5	38	71300	16.0	0.7
103 *	0.8La-0.2Ho	0	38	57800	—	-0.9
104	0.8La-0.2Ho	0.5	38	67300	16.4	-1.1
105 *	0.8La-0.2Er	0	38	57400	—	-0.4
106	0.8La-0.2Er	0.5	38	67200	17.0	-0.7
107 *	0.8La-0.2Tm	0	38	59100	—	-0.8
108	0.8La-0.2Tm	0.5	38	68100	15.3	-0.3
109 *	0.8La-0.2Yb	0	37	54300	—	-1.3
110	0.8La-0.2Yb	0.5	37	62400	14.9	0.1
111 *	0.8La-0.2Lu	0	37	56200	—	-1.2
112	0.8La-0.2Lu	0.5	37	63700	13.4	0.4
113 *	0.5La-0.2Nd-0.3Ce	0	38	61300	—	0.2
114	0.5La-0.2Nd-0.3Ce	0.5	38	68900	12.4	1.1
115 *	0.2La-0.4Sm-0.4Yb	0	36	56900	—	-1.7
116	0.2La-0.4Sm-0.4Yb	0.5	36	67000	17.8	-0.2
117 *	0.3La-0.4Eu-0.3Dy	0	34	55700	—	-2.8
118	0.3La-0.4Eu-0.3Dy	0.5	34	64300	15.4	-3.2

[0040]

Thereafter, 0.5 parts by weight based on 100 parts by weight of each major component of iron oxide (Fe_2O_3) was added to the each calcined powder, and moreover, an appropriate amount of a binder was added as shown in Table 4. Then, the mixtures were wet-crushed for 16 hours by means of a ball mill to obtain adjusted powders. The powders were processed in a similar manner as that for Example 1 to produce sintered pieces.

[0041]

For the sintered pieces, the dielectric constant (εr), the Q × f value, and the temperature coefficient (τ_f) of the resonance frequency were determined. Table 4 shows these results. In Table 4, the samples having sample-numbers with a star mark depart from the scope of the present invention, and all of the other samples are within the scope of the present invention.

[0042]

As seen in Table 4, for the sintered pieces each having a part of La substituted by another rare earth element, the Q × f value can be also enhanced by addition of Fe_2O_3 as seen in Samples having even numbers in the range of 81 to 118, as compared to Samples having no Fe_2O_3 added thereto (the Sample having the odd number which is smaller by 1 than each Sample having an even number).

[0043]

In the above-described Examples, iron oxide (Fe_2O_3) is employed as the compound containing Fe as an element. Compounds containing Fe as an element such as iron oxides of FeO and Fe_3O_4, sulfates, chloride or the like containing Fe as an element may be used. In this case, similar advantages can be also obtained.

[0044]

[Advantages]

The high frequency dielectric ceramic composition has a high Q value compared to the related art Re_2O_3 - Al_2O_3 - SrO - TiO_2 type material, and a high dielectric constant (ε_f) and a small temperature coefficient (τ_f) of the resonance frequency which are on the same level of those of the related art Re_2O_3 - Al_2O_3 - SrO - TiO_2 type material.

[0045]

Thus, the dielectric resonator, the dielectric filter, the dielectric duplexer, and the communication device, which are formed of the above-described high frequency dielectric ceramic composition, have superior characteristics, respectively.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is an illustrative cross-sectional view of a TE01δ mode dielectric resonator which is an example of the dielectric resonator of the present invention.

[Fig. 2] Fig. 2 is a perspective view of a TEM mode dielectric resonator which is another example of the dielectric resonator of the present invention;

[Fig. 3] Fig. 3 is a cross-sectional view taken along plane a - b of the dielectric resonator shown in Fig. 2; and

[Fig. 4] Fig. 4 is a block diagram of an example of the communication device of the present invention.

[Reference Numerals]

11, 21: dielectric resonator

12: metallic case

14, 22: dielectric ceramic

15: input terminal

16: output terminal

23a: inner conductor

23b: outer conductor

30: communication device

32: dielectric duplexer

34: transmission circuit

36: reception circuit

38: antenna

40: input-connecting means

42: output-connecting means

44: antenna-connecting means

46, 48: dielectric filer

50: external coupling means

JP Application No. 2002-253595

[Name of Document] ABSTRACT

[Abstract]

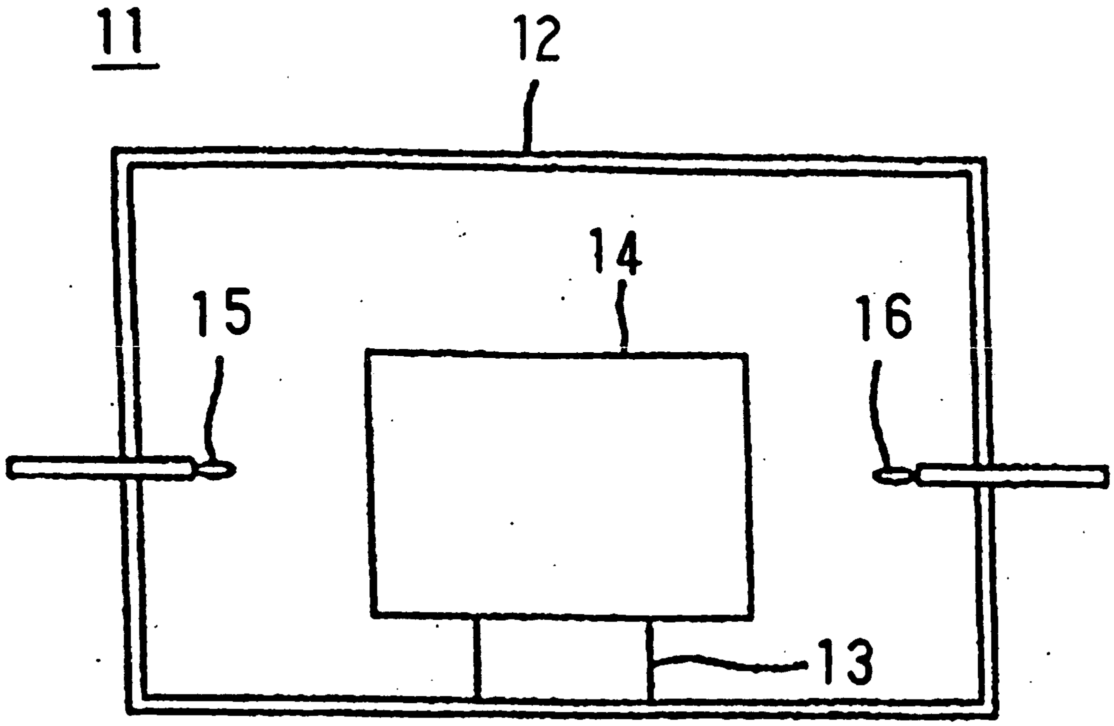
[Object] To provide a high frequency dielectric ceramic composition which has a high Q value compared with the related art Re_2O_3 - Al_2O_3 - SrO - TiO_2 type material, and a high dielectric constant (ε_f) and a small temperature coefficient (τ_f) of the resonance frequency which are on the same level of those of the related art Re_2O_3 - Al_2O_3 - SrO - TiO_2 type material.

[Solving Means] A high frequency dielectric ceramic composition includes: as a major component a composition which contains a rare earth element (Re), Al, Sr, and Ti as metal elements and has a composition formula expressed by a molar ratio of $aRe_2O_3 - bAl_2O_3 - cSrO - dTiO_2$ in which a, b, c, and d satisfy the following formula; $0.113 \leq a \leq 0.172$, $0.111 \leq b \leq 0.171$, $0.322 \leq c \leq 0.388$, $0.323 \leq d \leq 0.396$, and $a + b + c + d = 1.000$; and 0.01 to 2 parts by weight on a Fe_2O_3 conversion basis of Fe as an element, based on 100 parts by weight of the major component.

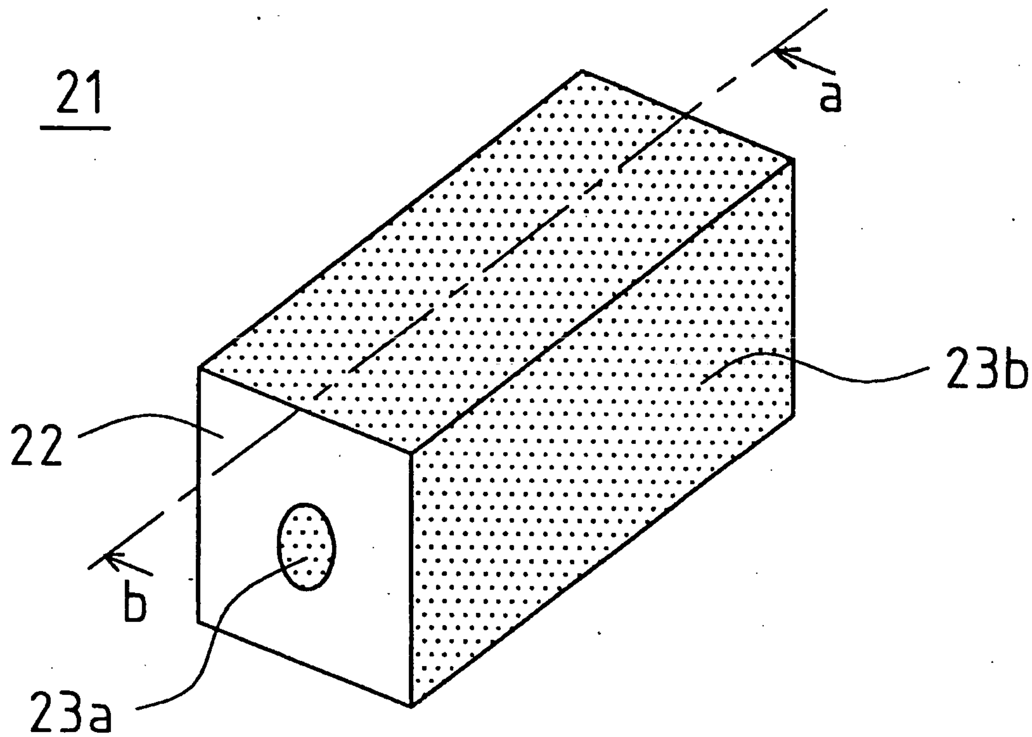
[Selected Figure] No Figure

[Name of Document] DRAWINGS

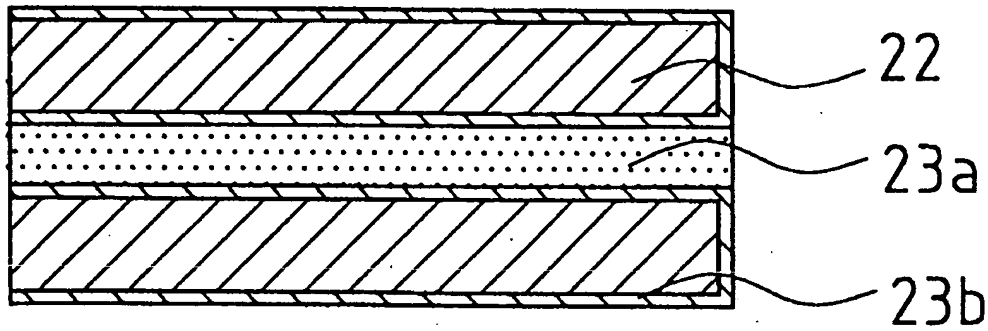
[FIG. 1]



.... [FIG. 2]



[FIG. 3]



.... [FIG. 4]